# OPTIMIZING THE COTTON AND COTTON/ MODAL BLENDED FABRIC PROPERTIES ON SINGLE JERSEY MACHINERY

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## Abstract

Knitted fabrics are widely used in clothing due to their unique stretch ability, which is completely different from the woven fabric behavior. All regenerated cellulosic fabrics have the same chemical composition, yet they differ in their molecular properties, which leads to different behaviors during their processing and in the final service ability of the produced garment. Therefore, the main objective of this research work is to optimize the single jersey machine setting, mainly the input tension, using different cotton and Modal blend ratio. In this research study, four different blends of cotton and Modal yarns (100% cotton, 50/50% Cotton / Modal, 70/30% Modal / Cotton and 100% Modal) were produced on the same knitting machine with different yarn input tension ranging from 2 CN to 14 CN. All the produced fabrics were half bleached and dyed under identical dyeing conditions and two different finishing methods. The dimensional properties, physical properties, some mechanical properties and shrinkage were measured for the produced fabrics.

## Introduction

Cellulose is a raw material widely used in the production of man-made textile fibers. T. Kreze et al. stated that all regenerated cellulosic fibers have the same chemical composition, but they differ in density, molecular mass, polymerization degree, molecular arrangement and the degree of crystallization. This will have a significant effect on the absorption properties and the mechanical properties.

For this reason the mixing of different cellulosic fibers represented a challenge for textile researcher to reach the optimum blending conditions for properties and comfort. El Mogazy et al. stated an analytical approach of fiber blending and the outcome of this blending was classified into: 1. Structural blending, 2. Attributive blending, 3. Appearance blending, and 4. Interactive blending. Results shows that modal fiber are harmonic with cotton and add advantage to cotton in terms of processing propensity due its superior fiber length and significant fineness. Nazan et al. studied the properties of ring, rotor, and vortex spun yarns produced from different yarn counts of cotton, viscose rayon, and 50/50 cotton-modal. The results show that vortex spun yarns have lower hairiness and better pilling resistance over ring and open-end rotor spun yarns. A. Gun et al. studied the dimensional and physical properties of plain knitted fabrics made from 50/50 bamboo/cotton. The result show that each fabric type knitted from bamboo/cotton, viscose/cotton and modal/cotton blended yarns behaves similarly. Although, the modal/cotton knitted fabrics have higher k values than the bamboo/cotton and viscose/cotton knitted fabrics. For physical properties, the results show that the weight, thickness and air permeability values are independent of the fiber type. Plain knitted fabrics from modal/cotton blended yarns have the highest bursting strength values. Plain knitted fabrics from bamboo/cotton blended yarns tend to pill less.

The yarn input tension in knitted fabric is another challenge to textile researcher Young-Seok found that yarn tension should be controlled in the best knitting conditions to reduce processing faults and to manufacture good quality knitted fabrics. Several researchers have been carried out on the effect of yarn in put tension in 100% cotton knitted fabric. Not one single research was found in the public domain about the effect of yarn in put tension on blended cotton and Modal fabrics. For this reason the aim of the research work is to optimize the single jersey machine setting, mainly the input tension, using different cotton and Modal blend.

## Materials and Methods

In this research work 100% cotton, 50/50 Cotton / Modal, 70/30Modal/Cotton and 100% Modal yarns were used to produce single jersey knitted fabrics. The following table (1) shows the main specifications and properties of the used yarns.

Table (1) Specifications of used yarns

| | 100% Cotton | 50%Modal/50%Cotton | 70%Modal/30%Cotton | 100% Modal |
|---|---|---|---|---|
| **Ne** | 29.5 | 29.4 | 29.5 | 29.5 |
| **$CV_{Ne}$ (%)** | 1 | 1.5 | 1.5 | 1.5 |
| **TPI** | 20.4 | 18.5 | 19.7 | 20.3 |
| **$CV_{TPI}$ (%)** | 1.5 | 1.6 | 1.6 | 1.9 |
| **Irregularity (CV %)** | 12.4 | 10.5 | 11.3 | 11.7 |
| **Thin places (-50%)** | 2 | 0 | 0 | 4 |
| **Thick places (+50%)** | 22 | 10 | 12 | 8 |
| **Neps** | 40 | 20 | 18 | 18 |
| **Breaking force(CN)** | 398 | 442 | 400 | 494 |
| **RKM ($Kg_f$*Nm)** | 20 | 22.5 | 20.3 | 25 |
| **RKM (CV %)** | 11 | 7.3 | 8 | 10 |
| **Elongation %** | 5.8 | 5.4 | 6.5 | 12 |
| **Elongation (CV %)** | 9.5 | 8.5 | 12.5 | 9 |
| **Hairness (H)** | 7.3 | 7.2 | 7 | 6.4 |
| **Hairness (SH)** | 1.9 | 1.7 | 1.7 | 1.6 |

## Fabric Production

All the fabric samples were produced on Mayer and Cie, S4-3.2 single jersey circular knitting machine. The loop length was kept constant at 2.8 mm. The following table (2) shows the main specification of the knitting machine used.

Table (2) Knitting machine specification

| | | | |
|---|---|---|---|
| **Machine Manufacturer** | Mayer & Cie | **Number of Feeders** | 84 |
| **Type** | S4 - 3.2 | **Total Number of needles** | 1944 |
| **Diameter** | 26" | **Actual Machine Speed** | 20 r.p.m |
| **Gauge** | 24 | **Loop Length** | 2.8 mm |

The fabrics were produced with different yarn input tension ranging from 2 CN to 14 CN. The yarn input tension was measured electronically in CN using MLT WESCO device.

## Fabric Finishing

All grey fabrics were half bleached and then dyed in the same manner with two different finishing lines. Then they were left to reach the full relaxed state. The following block diagram (Figure 1) compares between the two different methods of finishing the first method for the open width fabric finishing process and the second method for the closed form finishing process.

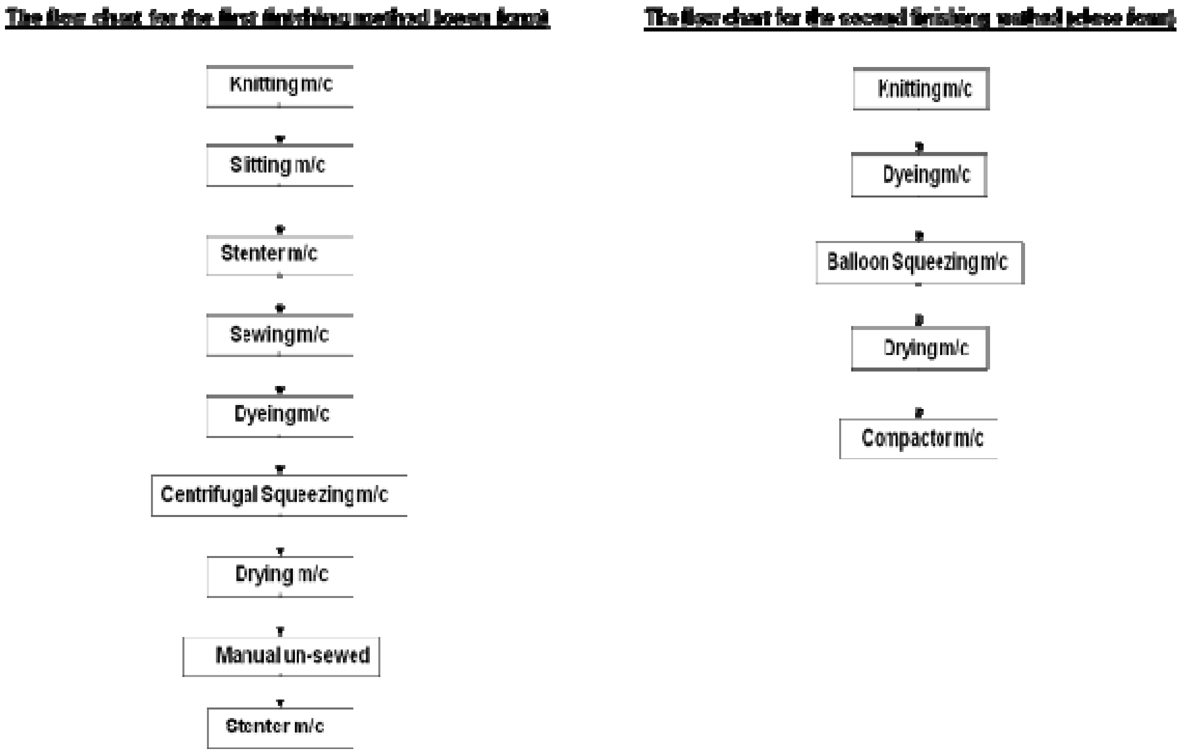


Figure (1) Different methods of finishing process

**Fabric Testing**

For the dimensional properties, the numbers of wales and courses /cm were measured according to ASTM D3887. Also the fabric loop length and shrinkage percentage were determined after five washes. As for the mechanical properties, bursting strength was measured according to ASTM D3786 and pilling was measured according to ASTM D3512 and air permeability by ASTM D 737. At last, the color difference of the same dyed fabrics was measured on the data color instrument. The 100% cotton sample at 6 CN tension for the open width fabric finishing process was taken as a reference sample during measurements.

As for the shrinkage % five cycles were carried out followed by tumble-drying. This helps the loops to approach their relaxed shape, which could be accepted as the minimum energy state. After loops reach their fully relaxed shape, the fabric becomes more dimensionally stable with fewer tendencies to shrink. 5 cycles of washing are approximately adequate for plain single jersey fabric to reach equilibrium or stable state.

## Results and Discussion

As stated before, the objective of this research work is to optimize the single jersey machine setting, mainly the input tension, using different cotton and Modal blend ratio. For this reason the effect of the Input tension and the blend ratio was tested using ANOVA. Than the affect of the different finishing methods (open width OW and closed width CW) were also tested using the t-test. The following section explains in details the results obtained.

**Effect of blend ratio and yarn input tension**

In order to demonstrate the effect of the blend ratio and the yarn input tension on values of the tested fabric properties under study, the results were analyzed using Anova: Two-Factor Without Replication. The analysis was carried out for the two methods of finishing used (OW and CW). According to ANOVA test results, the factors were considered to be significant at a P-value less than 0.05. The P-values and the significant levels of the ANOVA tests are shown in table (3).

Table (3) P-values of ANOVA test

| Fabric Property | | Yarn Input Tension | Blend Ratio |
|---|---|---|---|
| **Courses/cm** | OW | N.S. | 3E-05 |
| | CW | N.S. | 8E-05 |
| **Wales/cm** | OW | N.S. | N.S. |
| | CW | N.S. | 1E-04 |
| **Fabric Weight (g/m2)** | OW | N.S. | 4E-05 |
| | CW | N.S. | 4E-08 |
| **Loop Length (mm)** | OW | N.S. | N.S. |
| | CW | N.S. | N.S. |
| **Fabric Thickness (mm)** | OW | N.S. | 6E-07 |
| | CW | N.S. | 1E-07 |
| **Color difference (ΔE)** | OW | N.S. | 2E-05 |
| | CW | N.S. | 3E-07 |
| **Length Shrinkage %** | OW | N.S. | 0.004 |
| | CW | N.S. | 4E-04 |
| **Width Shrinkage %** | OW | N.S. | N.S. |
| | CW | N.S. | N.S. |
| **Bursting Strength (Ib/inch$^2$)** | OW | N.S. | 8E-08 |
| | CW | N.S. | 5E-06 |
| **Pilling** | OW | N.S. | 6E-04 |
| | CW | N.S. | 8E-04 |
| **Air Permeability(ft$^3$/min)** | OW | N.S. | 1E-07 |
| | CW | N.S. | 5E-10 |

N.S. = Non-significant  Sign. = Significant

As it can be seen from the last table the yarn input tension was found Non-significant in all the fabric properties, this may be due to the constant loop length, which is, as well known, the key factor for all the knitted fabric properties. Besides, Changing the yarn tension on the S4 knitting machine was achieved by using central cam adjustment, where the cam carrier with all cam segments were raised or lowered through this adjustment, and as a result this changes the distance between needle heads and knock-over edge of the holding-down / knocking over sinker. So, there is a more control to adjust all the cams and yarn feeders at the same yarn tension instead of adjusting every one individually which may lead to difference or error between the adjusted yarn tensions between all yarn feeders.

This is opposite to other references results of Dias, which stated that the loop length in the fabric becomes shorter when the yarn is under more tension, where the applied yarn tension ranges from 0 CN till 150 CN. This range of yarn tension values is excessive and is not commercially used during the actual production of the circular knitted fabric. Also, the resultant value of the loop length with changing yarn tension between 0 and 15 CN is approximately neglected for the actual working conditions.
On the other hand blending the cotton with modal fiber had a significant effect on all the properties except the loop length and the width wise shrinkage %, for both methods of finishing (OW and CW). Again this is due to the constant loop length as previously mentioned where the yarn being delivered positively at the same rate through the positive yarn feeding system.

The courses/cm is affected by changing the blend ratio. The reason of that is related to the packing density of the fabric produced from 100 % cotton yarn is different from the packing density of fabric produced from 100% modal yarn.

**The effect of finishing methods**

The effect of the finishing methods (OW and CW) was tested using t-test for the two samples assuming equal variances. The mean, variance, t-calculated and p-value are shown in table (4). The factor was considered to be significant at a P-value less than 0.05.

Table (4) t-test results

| Fabric property | | Mean | Variance | t-cal | p-value | |
|---|---|---|---|---|---|---|
| Courses/cm | OW | 19.87 | 0.55 | -0.02 | 0.981 | N.Sign |
| | CW | 19.88 | 0.549 | | | |
| Wales/cm | OW | 13.71 | 0.139 | -5.9 | 2E-06 | Sign |
| | CW | 14.54 | 0.174 | | | |
| Fabric Weight (g/m2) | OW | 125.5 | 42 | -1.4 | 0.171 | N.Sign |
| | CW | 129 | 57.6 | | | |
| Loop Length (mm) | OW | 2.828 | 3E-04 | 3.375 | 0.002 | Sign |
| | CW | 2.813 | 7E-05 | | | |
| Fabric Thickness (mm) | OW | 0.381 | 0.001 | 0.637 | 0.529 | N.Sign |
| | CW | 0.373 | 9E-04 | | | |
| Color difference (ΔE) | OW | 1.619 | 0.503 | -2.37 | 0.024 | Sign |
| | CW | 2.238 | 0.582 | | | |
| Length Shrinkage % | OW | 8.313 | 5.296 | -1.14 | 0.264 | N.Sign |
| | CW | 9.313 | 7.029 | | | |
| Width Shrinkage. % | OW | 10.66 | 3.457 | 8.332 | 3E-09 | Sign |
| | CW | 6.094 | 1.341 | | | |
| Bursting Strength (Ib/inch$^2$) | OW | 76.9 | 220.1 | -0.36 | 0.718 | N.Sign |
| | CW | 78.66 | 152.2 | | | |
| Pilling | OW | 2.094 | 0.174 | 0.227 | 0.822 | N.Sign |
| | CW | 2.063 | 0.129 | | | |
| Air Permeability (ft$^3$/min) | OW | 406.4 | 21860 | 1.117 | 0.273 | N.Sign |
| | CW | 350.3 | 18538 | | | |

It is clear that the finishing method has an effect on the color difference, widthwise shrinkage, loop length and wales density where for the open width method, the fabric was stretched widthwise excessively and passed inside the Stenter machine through four chambers under a certain temperature and a certain steam pressure for a long time. Therefore, this technique has the ability to alter the color shade and the widthwise shrinkage of the processing fabric, because these properties are very sensitive to heat and pressure.

The following charts represent the effect of the blend ratio and the fabric finishing method on some of the tested properties:

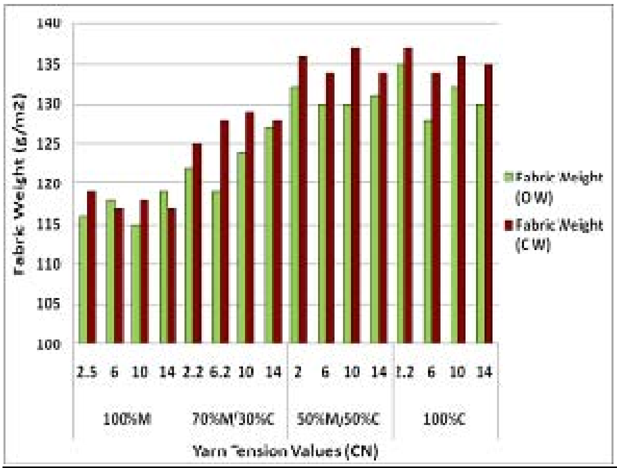


Figure 2. Fabric Weight (g/m2) values at different yarn input tension for different blend ratio

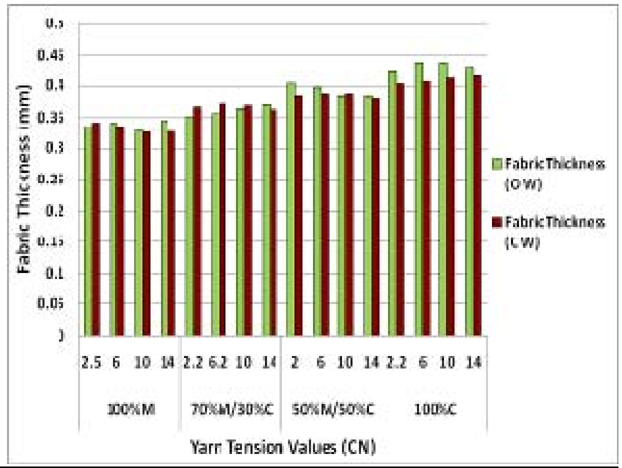


Figure 3. Fabric Thickness (mm) values at different yarn input tension for different blend ratio

Although all the fabric samples were knitted at the same loop length, the resultant finished fabric weight and thickness for the 100 % modal is smaller than 100 % cotton (see Figures 2 and 3), which is related to the higher courses density for the fabric knitted from 100 % cotton. Due to the high elongation degree of the 100% modal yarn, its fabric sample will have the possibility to be stretched in the lengthwise direction during the dyeing process inside the overflow dyeing machine and as a result its courses spacing will be more and this means a lower courses density.

Moreover, the modal yarn is more regular and has a very soft and smooth surface. This means that any twists inserted to its contained fiber (during the spinning process) give the yarn the compactness towards its center and this make the yarn to have a low diameter and a high packing density and consequently gives a fabric with a low thickness value.

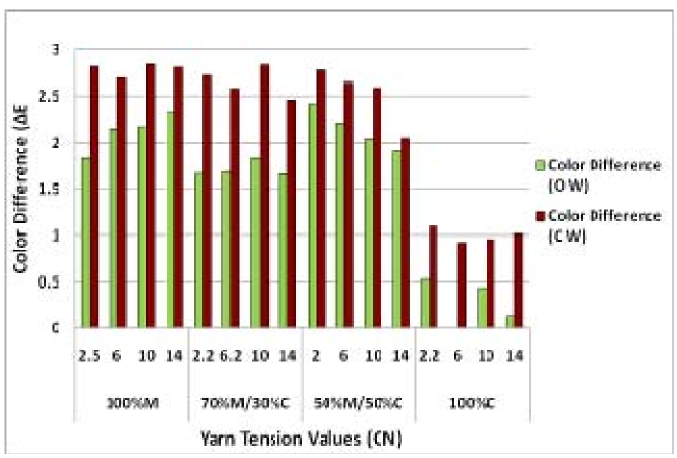


Figure 4. Color Difference (ΔE) values at different yarn input tension for different blend ratio

Figure (4) shows that, fabrics knitted from 100% modal yarns show darker colors compared to fabrics knitted from 100 % cotton yarns even though all the yarns are knitted on the same knitting machine and also all the fabric samples are dyed in the same dyeing bath. Therefore, it can be concluded that the modal yarns have a higher absorption capability (Kreze *et al.* 2003 & Zdenka *et al.*2002). This means that the required color shade can be achieved with less amount of dye stuff, thus reducing the cost of dyeing.

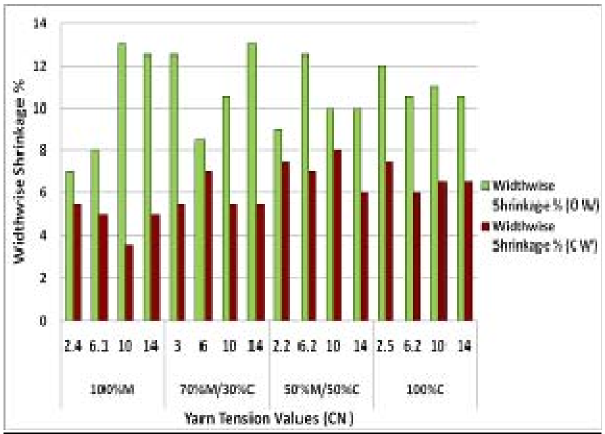


Figure 5. Widthwise Shrinkage % values (Fifth Wash) at different yarn input tension for different blend ratio

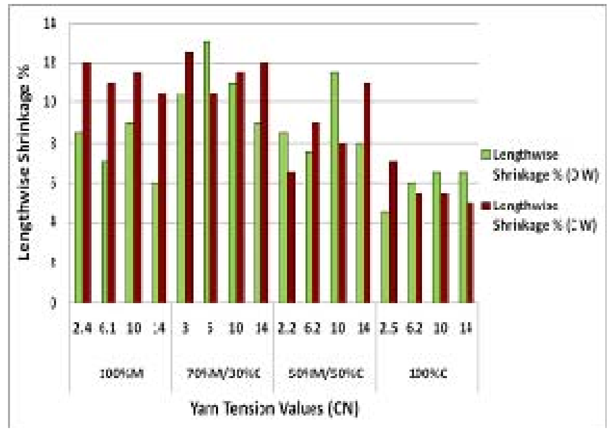


Figure 6. Lengthwise Shrinkage % values (Fifth Wash) at different yarn input tension for different blend ratio

The width and length shrinkage values of dyed fabrics after the fifth washing cycle are shown in Figures 5 and 6. The lengthwise percentage decreases as the percentage of the cotton increases inside the yarn while the widthwise shrinkage slightly increases as the percentage of cotton fibers inside the fabric become more. Fabrics produced from yarns containing more modal fibers percentage shrink somewhat less widthwise than others contained more cotton fibers, because they are more width dimensionally stable due to its better extensibility. Furthermore, the knitted samples finished through the first finishing method (open width form) gives more widthwise shrinkage degree than the second finishing method (close width form). This can be attributed to the influence of the Stenter machine which stretches the fabric greatly in the width direction during this finishing line.

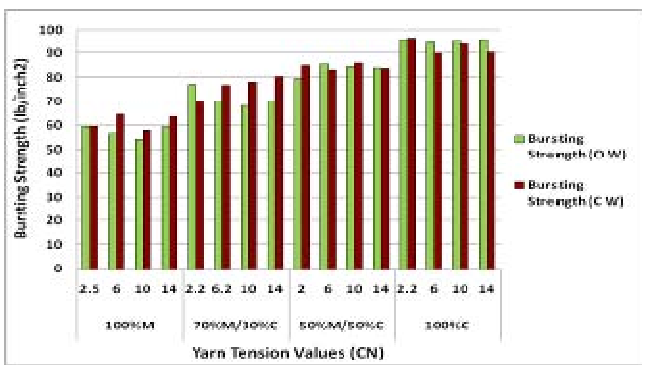


Figure 7. Bursting Strength (lb/inch2) values at different yarn input tension for different blend ratio

Bursting strength test results of open and closed finished fabric samples are shown in Figure 7. The test results indicate that the bursting strength of the fabric produced from 100% cotton were generally higher compared to 100% Modal. Despite of the higher breaking force of the 100 % modal yarn compared to 100% cotton yarn.

Due to lower hairiness level of the 100 % modal yarn which means smoother surface, higher mobility degree and less friction between loops. As a result the fabric could be easily penetrated during the bursting strength test and become a weaker fabric. i.e. as the cotton percentage increases the yarn hairiness increase and there is a high friction forces between the loops as pointed out earlier (Candan *et al.* 2002).

In addition, the bursting strength degree increases as the percentage of the cotton increases inside the yarn. The degree of freedom of the yarn mobility inside fabric tends to be more as the proportion of the modal fiber inside the yarn become greater. Therefore, the modal fabrics can't be recommended to garments which need high strength in use such as sportswear.

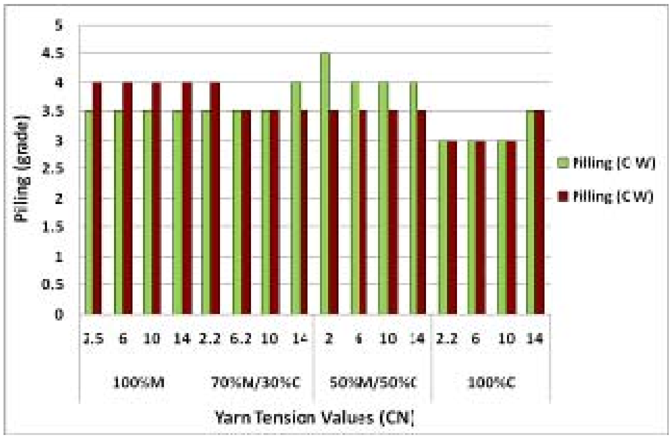


Figure 8. Pilling (grade) at different yarn input tension for different blend ratio

The pilling resistance of plain jersey knitted fabrics produced from 100 % modal yarns is better than those constructed from 100 % cotton yarns, as seen in Figure 8. This may be because the cotton yarns are more hairy than the modal yarns (see table 1), which may allow easy exposure of raised fiber ends to abrading forces and more fuzz is produced. In addition, the well aligned of the modal yarn may not promote easy fiber wear-off and as a result tend to have a less tendency to pill. The trend in less pilling is obvious as the yarn becomes leaner since the decrease in hairiness in lean yarn is greater in extent (Candan *et al.* 2002).

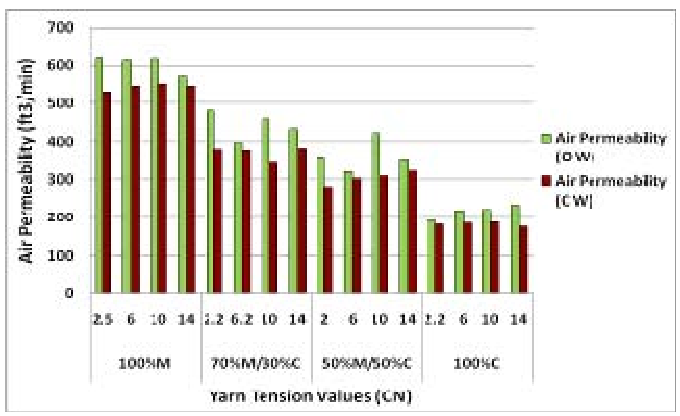


Figure 9. Air Permeability (ft3/min) values at different yarn input tension for different blend ratio

Although all the fabric samples were knitted with the same loop length, the air permeability of fabrics knitted from the 100 % modal yarns are greater than others produced from 100 % cotton yarns as shown in Figure 9, which may be explained in terms of more yarn hairiness of the 100 % cotton yarns which make the fibers protruding from the loops inside the fabric to become entangled. Consequently the openings and gaps contained in this knitted sample will be small. Additionally, modal is soft, smooth and breathes well.

Furthermore, the high packing density of the modal yarn and the low courses density of the modal fabric may be considered as another important reason for having high air permeability degree.

## Summary

The main objective of this research work is to optimize the single jersey machine setting, mainly the input tension, using different cotton and Modal blend ratio. Four different blends of cotton and Modal yarns (100% cotton, 50/50 Cotton / Modal, 70/30Modal/Cotton and 100% Modal) were produced on the same knitting machine with different yarn input tension ranging from 2 CN to 14 CN. All the produced fabrics were half bleached and dyed under identical dyeing conditions and two different finishing methods open width and closed width. The dimensional properties, physical properties, some mechanical properties and shrinkage were measured for the produced fabrics.

Yarn input tension was found Non-significant in all the fabric properties under study, this may be due to the constant loop length, which is, as well known, the key factor for all the knitted fabric properties. On the other hand blending the cotton with modal fiber had a significant effect on all the properties except the loop length and the width wise shrinkage %, for both methods of finishing (OW and CW). It was found also that the finishing method has an effect on the color difference, widthwise shrinkage, loop length and wales density.

Results show that mixing Modal with cotton improved some of the produced fabric properties. For example pilling resistance of plain jersey knitted fabrics produced from 100 % modal yarns is better than those constructed from 100 % cotton yarns. This may be because the cotton yarns are more hairy than the modal yarns. Also the air permeability of fabrics knitted from the 100 % modal yarns are greater than others produced from 100 % cotton yarns.

On the other hand the bursting strength of the fabrics produced from 100% cotton was generally higher compared to 100% Modal. Despite of the higher breaking force of the 100 % modal yarn compared to 100% cotton yarn. Due to lower hairiness level of the 100 % modal yarn which means smoother surface, higher mobility degree and less friction between loops. As a result the fabric could be easily penetrated during the bursting strength test and become a weaker fabric. For this reason care should be taken when using modal fabrics in sports garment especially at the knee and elbow area.

Fabrics knitted from 100% modal yarns show darker colors compared to fabrics knitted from 100 % cotton yarns even though the yarns are knitted on the same knitting machine and also dyed in the same dyeing bath. Therefore, it can be concluded that the modal yarns have a higher absorption capability. This means that the required color shade can be achieved with less amount of dye stuff, thus reducing the cost of dyeing.

## Acknowledgements

The authors gratefully wish to express their thanks to El Nasr Clothing and Textile Company (KABO) for their collaboration and contribution to the experimental part of the study.

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